



Howard, J., & Gibson, M. (2017). Frequency-dependent female genital cutting behaviour confers evolutionary fitness benefits. *Nature Ecology and Evolution*, 1, [49]. <https://doi.org/10.1038/s41559-016-0049>

Peer reviewed version

Link to published version (if available):
[10.1038/s41559-016-0049](https://doi.org/10.1038/s41559-016-0049)

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Published in *Nature Ecology & Evolution*

Howard, JA and Gibson, MA. (2017) *Nat Ecol Evo* 1: 0049

doi:10.1038/s41559-016-0049

Frequency-dependent female genital cutting behaviour confers evolutionary fitness benefits

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Abstract

Female genital cutting (FGC) has immediate and long-term negative health consequences that are well-documented, and its elimination is a priority for policy makers. The persistence of this widespread practice also presents a puzzle for evolutionary anthropologists due to its potentially detrimental impact on survival and reproductive fitness. Using multilevel modelling on Demographic Health Survey (DHS) datasets from 5 West African countries, here we show that FGC behaviour is frequency-dependent; the probability that girls are cut varies in proportion to the FGC frequency found in their ethnic group. We also show that this frequency-dependent behaviour is adaptive in evolutionary fitness terms; in ethnic groups with high FGC frequency women with FGC have significantly more surviving offspring than their uncut peers and the reverse is found in ethnic groups with low FGC frequency. Our results demonstrate how evolutionary and cultural forces can drive the persistence of harmful behaviours.

Female Genital Cutting (FGC) is defined by the World Health Organisation (WHO) as “all procedures that involve partial or total removal of the external female genitalia, or other injury to the female genital organs for non-medical reasons”¹. The severity and context in which it is practiced varies greatly, but the negative health consequences for women, particularly those with the more severe types of FGC ²⁻⁴ include short-term⁵, long-term ^{6,7}, obstetric ^{4,8}, and psychological and sexual problems ⁹. Occurring in 29 countries in Africa and the Middle East, the frequency of FGC within ethnic groups varies from 1-99% ¹⁰. The persistence of this practice, especially in the face of longstanding eradication efforts, represents a puzzle to policy makers and evolutionary scientists alike ¹¹⁻¹³. As a seemingly costly behaviour, FGC challenges assumptions of adaptive behaviour as it appears to jeopardise rather than maximise evolutionary fitness¹⁴.

Here we explore how evolutionary genetic and cultural forces may explain the persistence of FGC once established in a population. The relative importance of genetic versus cultural evolution in shaping human behaviour represents a long-standing debate within human evolutionary sciences¹⁵. In this study we build on a growing body of work and integrate ideas from cultural evolution and behavioural ecology to identify how and why reproductive outcomes (fitness) of FGC may vary according to the local cultural context ¹⁶⁻¹⁹.

Cultural evolution considers how human behaviours are socially transmitted ¹⁷⁻¹⁹. Positive frequency-dependent transmission is a well-established mechanism of social learning in which the probability that an individual adopts a behaviour depends on how common the behaviour is within a relevant group ^{20,21}. Conformity bias is a subset of positive frequency-dependent biases, where individuals are disproportionately likely to acquire the most common behaviour ²². It is often used as an explanation for the spread of neutral or maladaptive behaviours, as behaviours are adopted based on frequency without evaluation of merit. To date studies of conformity have mostly used modelling and

experimental data, however positive frequency-dependent transmission is gaining popularity as an explanation for FGC persistence^{23,24} and evidence of frequency-dependent maintenance of FGC has been found in one empirical study²⁵.

Consideration of social mechanisms underpinning the persistence and abandonment of FGC have also been incorporated within development policy and practice^{10,26,27}. A widely adopted explanation for FGC is based on coordination game theory and commonly known as the social convention theory²⁸. This suggests that men and women are stuck in a self-enforcing convention where both believe FGC is essential for marriage. It proposes that to alter behaviour a coordinated effort is required among individuals from an intra-marrying population so that a critical mass reach a tipping point and switch together from a cutting to a non-cutting convention. Although influential in eradication programmes application of this theory to FGC behaviour has been challenged; a recent study found a range of cutting practices within intermarrying communities, inconsistent with a social convention norm²⁹, and other studies found that access to women's social networks³⁰ or women's individual or household variables³¹ are more important in perpetuating FGC.

Behavioural ecology considers the ultimate mechanisms^{32,33,34} of behaviour and predicts that individuals will behave in a way that maximises reproductive success given their specific circumstances despite any negative effects this may have on their immediate wellbeing^{16,35}.

Behaviour is expected to lead to fitness maximisation within the constraints of the local ecology (including socio-ecology). Applying this to FGC, we would expect FGC to persist when the balance of the costs and benefits result in fitness benefits for those involved. Proposed benefits resulting from FGC include enhanced marriageability (see Ross et al²⁴) or membership of social networks with associated access to resources and/or support³⁰. To date, only a few studies have explored the impact of FGC status on proxies for fitness, with mixed results; two studies found FGC to be

associated with greater fertility ^{36 37} while another found a negative association between fertility and FGC ³⁸. None of these studies explored the frequency-dependent nature of FGC.

Data & Methods (see Extended Methods below for further detail)

Here we test two predictions; 1) FGC is a frequency-dependent behaviour, and 2) there are fitness benefits associated with frequency-dependent FGC behaviour. We selected five Demographic and Health Surveys Program (DHS) datasets from West Africa according to specific inclusion criteria. (See Supplementary Table 5 and Supplementary Figure 1 for inclusion analysis and map). This provided data on 61,483 women with known FGC status from 47 ethnic groups, of whom 36,038 have one or more living daughter and provided information on their daughter(s)' FGC status. All individuals who met these criteria were included. Analysis (not presented here) showed that similar patterns were found when using the FGC prevalence in the mother or father's ethnic group as the predictor of interest; to maintain sample size mother's ethnic FGC prevalence was used. To test both predictions we performed single level analysis for ethnic groups from each of the five countries separately, as well as multilevel analysis which pooled the women's data from all five countries to examine individual variation. The three level model structure used individual women, nested in ethnic groups, nested in countries. In both single- and multi-level analyses the same dependent and independent variables were used.

To test the first prediction we used logistic regression to examine whether the FGC prevalence in a mother's ethnic group is significantly associated with the FGC status of her daughter(s). The dependent variable was a binary response of whether or not a mother has one or more cut daughter(s). The key independent variable of interest was the FGC frequency in the mother's ethnic group, controlling for the mother's own FGC status as well as a range of maternal variables that have been found in previous studies to be significantly associated with the likelihood of a daughter being cut namely the mother's age, wealth, education and religion ³⁹⁻⁴¹.

To test the second prediction we used linear regression to examine the relationship between ethnic FGC frequency and the relative fitness of women with and without FGC by ethnic group. We used the number of surviving offspring at age 40 as a proxy for fitness in the analysis, as the upper age limit of female respondents in DHS surveys is 49 years and few have completed lifetime fertility. This provided a sample of 10,067 women aged 40-49 years from 47 ethnic groups, who had given their FGC status. We performed a Pearson's correlation by country separately, to examine the relationship between ethnic FGC frequency and average number of surviving offspring for women with and without FGC in each ethnic group. We also performed a three level linear regression analysis controlling for individual level 1 variables; mother's FGC status, education, religion and wealth, and ethnic FGC frequency was added as a level 2 contextual variable. A cross-level interaction between FGC status and ethnic FGC frequency was included which allowed for the effect of FGC status to vary depending on FGC prevalence in the ethnic group. All analyses were undertaken using MLwiN version 2.35 and SPSS v23.

RESULTS

Prediction 1: FGC is a frequency-dependent behaviour

As FGC prevalence in the mother's ethnic group increases, the odds of the mother having a cut daughter also increases. The single-level logistic regression model showed that mother's FGC status is the strongest predictor, followed by ethnic FGC frequency, which is a significant predictor of whether a mother has a cut daughter when holding other variables constant in all five countries (OR, 95% CI; Nigeria 1.019 (1.014, 1.023), Senegal 1.013 (1.007, 1.018), Mali 1.024 (1.020, 1.028) , Burkina Faso 1.015 (1.007, 1.023), Ivory Coast 1.031 (1.020, 1.044), $p < 0.001$ for all). See Supplementary Table 1 for full results. With every 1% increase in FGC prevalence in the mother's ethnic group there is a 1.3% - 3.1% increase (depending on the country) in the odds of her daughter being cut which in areas of high FGC prevalence translates into a substantial increase in odds. The interaction plot

(Figure 1) illustrates these results. In all five countries the probability of a mother having a cut daughter is higher where ethnic FGC frequency is high, both for women with FGC and to a lesser extent women without FGC, with the exception of Mali.

[Insert Figure 1 here]

Three-level logistic regression analysis exploring unobserved variation in whether a mother has a cut daughter (due to maternal, ethnic and country-level factors) reveals significant clustering at the ethnic group level (see Supplementary Table 2 for full results). After controlling for both maternal and ethnic level factors there is significant variation in the odds of having a cut daughter across ethnic groups ($u_{jk} = 0.241$ S.E. 0.064) but not across countries ($v_{jk} = 1.313$ S.E. 0.848). The proportional change in variance across ethnic groups showed that much of the individual variance in log odds of having a cut daughter is explained by maternal factors (78%), but that inclusion of ethnic FGC prevalence improves the model fit and together explains 90% of the variance. The median odds ratios (MOR) at ethnic group level showed the same effect (see Supplementary Table 2).

Allowing for variation within ethnic group and country, the multilevel logistic model also showed that ethnic FGC frequency is a significant predictor of whether a mother has a cut daughter when controlling for the mother's own FGC status as well as her age, wealth, religion and education (OR 1.022, 95% CI (1.015, 1.029)) (full results shown in the Supplementary Table 2). In this model with every 1% increase in ethnic FGC prevalence, a mother has a 2.2% increase in the probability of having a cut daughter when holding these other variables constant. Figure 2 illustrates the predicted probabilities.

[Insert Figure 2 here]

In support of previous studies having FGC, being Muslim and being older increases the odds of a mother having a cut daughter, whereas being educated and wealthy decreases the odds^{41,42}. Here we also show that ethnic FGC frequency is a significant factor in determining the probability that a mother will have a cut daughter.

Prediction 2: Fitness benefits associated with frequency-dependent FGC behaviour

The results from the single- and multi-level analysis demonstrate that fitness, measured by the number of surviving offspring at age 40 years, is increased by varying FGC behaviour in relation to ethnic FGC frequency. In all five countries the univariate correlation analysis showed a strong positive association between the ethnic FGC frequency and the percentage difference in the average number of surviving offspring for women with FGC compared to women without (see Table 1, illustrated in Figure 3). In ethnic groups with high FGC prevalence, on average women with FGC have more surviving offspring than women without FGC in the same ethnic group. Conversely, in ethnic groups with low FGC prevalence women without FGC have more surviving offspring on average. The average number of surviving offspring ranges from 5.4 – 7.3 among ethnic groups in this study therefore a 20% difference is equivalent to approximately one offspring (Figure 3).

[Insert Figure 3 here]

The cross-level interaction In the multilevel linear regression model allows for the effect of individual FGC status (level 1) to vary depending on FGC prevalence in the ethnic group (level 2)^{43 44}. This is significant when controlling for maternal characteristics (β 0.008, \pm 0.003, p 0.005). The effect is illustrated in Figure 4 where the predicted number of surviving offspring are plotted for women with and without FGC over a range of ethnic FGC frequencies. As ethnic FGC frequency increases the fitness advantages shifts from women without FGC to women with FGC. In absolute terms women

with FGC are predicted to have 0.34 fewer surviving offspring in ethnic groups with 0% FGC prevalence, and 0.44 more surviving offspring in ethnic groups with 100% FGC prevalence.

[Insert Figure 4 here]

DISCUSSION

Frequency-dependent behaviour

We show in both single- and multilevel analysis that FGC frequency in the mother's ethnic group is a significant predictor of the odds of having a cut daughter, when controlling for maternal characteristics including mother's FGC status. In all five countries, the odds increase as the ethnic FGC frequency increases which supports our prediction that FGC is a frequency-dependent behaviour.

Both Figures 1 and 2 illustrate that the mother's FGC status is the strongest predictor, however the relationship between a mother's and her daughters' FGC status is not simply linear with mothers replicating their own status on their daughters. Women with FGC have a markedly lower probability of having a cut daughter in ethnic groups with low compared to high FGC frequency showing that they are responsive to local ethnic pressures. By contrast, women without FGC are unlikely to perpetuate FGC even when living in an ethnic group where FGC is highly prevalent suggesting that ethnic FGC frequency has less impact on their behaviour (with the exception of Mali). This implies that the forces of frequency-dependent learning may not work equally in both directions and that once the behaviour has been abandoned it may not be resumed even when individuals become exposed to high FGC prevalence, for example through migration or marriage.

Fitness benefits associated with frequency-dependent behaviour

We also show that frequency-dependent FGC behaviour confers evolutionary fitness benefits, as measured by the number of surviving offspring at age 40. Results from both the single and multi-level models demonstrate that in ethnic groups with high FGC frequency women with FGC have higher relative fitness while the reverse is true in ethnic groups with low FGC frequency. Further, that despite the negative health consequences, women with FGC are at a fitness advantage compared to women without FGC when living in ethnic groups where FGC is the majority behaviour.

Selection biases relating to biological phenotypic differences between women with or without FGC are unlikely to explain these results as a) women with FGC only have higher fitness in circumstances where FGC is the majority behaviour rather than universally, otherwise they have equal or lower fitness, b) excluding women with extreme FGC types which may be driving the fitness differences among high FGC ethnicities does not change the results (Supplementary Information Table 3) and c) women with FGC are not taller (a proxy for well-being and associated with fertility^{45,46}), and therefore does not account for the fitness differences seen here (Supplementary Information Table 4). Further, there is enough variability in sex differences in infant and child mortality to demonstrate that there is no clear mortality bias for girls that could be associated with the FGC procedure (Supplementary Information Table 4). However, it is possible that maternal mortality associated with FGC could introduce bias and underestimation of the costs of FGC as women who died before age 40-49 are not included in the DHS surveys.

These frequency-dependent findings may explain the varied results from previous studies examining the association between proxies for fitness and FGC status, as FGC frequencies among local populations were not considered^{36,37,38}. Rather the results of this study reveal that women with FGC should only have higher reproductive success in populations where FGC is the dominant behaviour.

Figure 3 and Figure 4 show that at 50% ethnic FGC prevalence, women with and without FGC have similar fitness. Interestingly mid-range FGC prevalence is uncommon; in our sample only 4% of ethnic groups have an FGC frequency between 45-55%, and the same distribution is found among a further 18 DHS countries. This implies that prevalence in ethnic groups is moving toward either 0% or 100% and accordingly we suggest that eradication policy should seek to reduce prevalence among ethnic groups to less than 50%. If individuals are then disproportionately likely to acquire the most common behaviour FGC frequency will gradually reduce over time ²¹. Time series data, however, would be necessary to confirm this prediction.

CONCLUSION

In this study we show how female genital cutting, which is an often-used example of a costly behaviour in humans, can be adaptive in evolutionary fitness terms. We show that FGC is a frequency-dependent behaviour and that the benefits of FGC, measured by the number of surviving offspring, outweigh the costs in circumstances where FGC is dominant. It is striking that these positive frequency-dependent results are repeated in five countries with quite different contexts and FGC eradication efforts. To our knowledge this is the first study to demonstrate the fitness consequences associated with a frequency-dependent socially transmitted behaviour. We show that as the cultural context (ethnic FGC frequency) gradually changes, so too does behaviour, resulting in optimal fitness at both ends of the spectrum. Women who do not follow the majority behaviour appear to be at a fitness disadvantage, and conversely those who follow the majority behaviour are at a fitness advantage.

We argue that combined cultural-evolutionary forces underpin these effects. Responding to the majority behaviour could, for example, enhance the ‘mate value’ of women by increasing their desirability in the marriage market which may translate into higher fertility and/or improved child survivorship⁴⁷. Studies linking FGC status with early age at first marriage ^{36,48} and age at first birth ⁴⁹ are supportive of this. Further, if FGC status provides entry into social networks with enhanced access

to resources and support this may also improve fitness outcomes such as the health of women and their offspring³⁰.

Understanding that frequency-dependent forces lead to the persistence of FGC, and that this may have fitness benefits, is a novel contribution to the debate in the evolutionary literature on how and why costly behaviours are perpetuated. These findings are also important for policy makers as they reveal why FGC, and similar costly behaviours, are resistant to change. Specifically, these results imply that FGC eradication initiatives based on the idea of a tipping point driving behavioural change may not be the only solution²⁶. Instead a piecemeal reduction of FGC by individuals can play a part in the decline of FGC prevalence in the overall population.

EXTENDED METHODS

a) Demographic and Health Surveys (DHS)

We used data from the Demographic and Health Surveys Program (DHS) which surveys large numbers of women across different countries in a comparable format. All respondents are read an informed consent statement before interview, following which they may accept or decline to participate. A parent or guardian provides consent prior to participation by an adolescent. Countries from West Africa, where FGC is highly prevalent, were included according to specific criteria; a) a recent DHS survey included the FGC module, b) the population exceeds 3 million for sample size purposes, and c) the FGC frequencies of ethnic groups within the country range from under to over 50%. This last criterion was essential to explore FGC behaviour and fitness consequences in a wide range of FGC frequencies. The following five datasets met these criteria; Ivory Coast 2011-12, Mali 2006, Nigeria 2008, Burkina Faso 2010 and Senegal 2013 which together provided data on 61,483 women from 47 ethnic groups. Female respondents in all DHS surveys are aged 15-49 years old, and

are a representative sample by socioeconomic status and ethnicity. See Supplementary Table 6 and Supplementary Figure 1 for inclusion analysis and map.

Ethnicity was used as the relevant group or context for frequency-dependent analysis, as ethnic group has been shown to have a significant effect on FGC prevalence^{50,30,31,51} and provides an adequate sample size for analysis. Cluster and region were considered as alternative reference groups but rejected as neither are necessarily meaningful social groupings; regional divisions are often arbitrarily drawn for administrative purposes, and clusters group together households within a similar radius of a specific GPS point but with unknown inter-relationships. Mothers' rather than fathers' ethnic group was used to maintain sample size. Interethnic marriage rates range from 8-27% although most interethnic marriages are between couples from ethnic groups with 10% or less difference in FGC prevalence. Ethnic groups found in multiple study countries were treated separately in the analysis as the individuals within them are subject to different legal and national pressures. At the time of these DHS surveys FGC was illegal in Ivory Coast, Burkina Faso, Senegal, but legal in Mali and some states of Nigeria. See Supplementary Table 6 for a breakdown of respondents' FGC status by ethnic group and country.

Mothers and older female relatives are usually the main proponents of FGC and arrange a girl's FGC procedure, most commonly by a traditional practitioner^{52,53}. In West Africa, FGC is usually performed during infancy or before age five and in the five study countries 76-94% of girls with FGC were cut before age five⁴².

b) Statistical analysis

As noted above both single and multilevel models were used to test both predictions below. The data is well suited to multilevel regression models, with individual women nested in ethnic groups, nested in countries. This structure was used to explore individual and contextual ethnic level factors

associated with the outcome variables. Recognising this clustering within a multilevel model distinguishes between the individual and higher-level variation avoiding incorrect inferences based on ecological fallacies⁵⁴. However, although there is no consensus on sample size for multilevel analysis, it is generally recommended that it should be over 15 to avoid standard errors being underestimated⁴³. Here we have just 5 countries at level 3 and note there is a possibility that the country-level random variances and standard errors may be underestimated.

Prediction 1: FGC is a frequency-dependent behaviour

Here we test the prediction that there is a significant association between ethnic FGC frequency and the odds of a mother having a cut daughter. The survey asked women with at least one living daughter whether their daughter had been 'circumcised' (translated into the local term). In some countries the FGC status of every daughter was collected, and in others future intentions towards uncut daughters were collected, but to keep the data comparable across all five countries we used a single indicator of whether one or more daughters had been cut at the time of the survey. Ethnic FGC frequency was calculated as a percentage for each identifiable ethnic group in each country by dividing the number of women with FGC by the total number of women who responded to the survey question on whether they had been circumcised. Those whose ethnic group was given as 'other' were excluded. In the model the input variables, including the FGC frequency in each ethnic group, concern only the mothers, and the outcome variable concerns their daughters. This resulted in 36,038 mothers from the 47 identifiable ethnic groups, who had at least one daughter and provided information concerning their own and their daughter's FGC status. All available data that met these criteria were used in the analysis.

The single level logistic regression by country included all predictor variables (ethnic FGC frequency, mother's FGC status, religion, education, wealth and age). In the three level logistic regression model (level 1: individual n36,038, level 2: ethnic group: n47, level 3: country n5) individual and contextual

ethnic group variables were added separately. Although no covariates in the model relate to country (level 3) it was retained in the model to allow for analysis of residual variance at this level. We constructed 4 models; the first model was a null model without any variables, the second contained only individual-level variables, and the third additionally included the contextual level 2 variable of ethnic FGC percentage.

The logit multilevel model uses binomial distribution assumptions with second order linearisation and a penalised quasiliikelihood (PQL) estimation type⁴³. Continuous individual level variables (age) are centred around their grand mean, to ensure that higher level associations are adjusted for individual level characteristics. The model is expressed as;

$$\text{Logit } \pi_{ijk} = X'_{ijk} \beta + u_{jk} + v_{jk} \quad (1)$$

where π_{ijk} is the probability of having a cut daughter for an individual mother i , in the j th ethnic group in the k th country; X'_{ijk} are the covariates defined at levels 1 – 3 and u_{jk} and v_{jk} are the residuals at the ethnic and country level respectively. We constructed 4 models; the first model was a null model without any variables, the second contained only individual-level variables, the third additionally included the contextual level 2 variable of ethnic FGC percentage, and the fourth additionally included a cross-level interaction between mother's FGC status and ethnic FGC percentage.

To calculate or partition the variance attributable to different levels within the model, two different measures were calculated as described by Goldstein⁵⁵, and Snijders and Bosker⁵⁶. The intra-class correlation coefficient (ICC), expressed as a percentage, gives a measure of the variance in the logistic outcome attributable to different levels in the model. The median odds ratio (MOR) translates the level 2 or 3 variance into the odds ratio scale, and gives an indication of the increased risk of the outcome, in this case the extent to which the individual probability of having a cut

daughter is determined by ethnic group or country. Both help to interpret the importance of the ethnic group (level 2) and country (level 3) on the individual woman's propensity to have a cut daughter. The MOR and ICC are calculated as follows;

$$\text{MOR} = \exp(0.95 \sqrt{U_{jk}}) \quad (2)$$

$$\text{ICC} = U_{jk} / (U_{jk} + 3.29) \quad (3)$$

Predicted probabilities were calculated according the SPSS and MLwiN defaults which set other continuous parameters to their mean average value, and other categorical parameters to the proportion of cases in each category.

Prediction 2: Fitness benefits associated with frequency-dependent FGC behaviour

Here we test the prediction that there are fitness benefits associated with frequency-dependent FGC behaviour. Few women in the DHS have completed lifetime fertility, so as a proxy for fitness we used an age-specific measure; the total number of offspring born and still alive when the mother was 40, excluding pregnancies. Age 40 gives an adequate sample size and is sufficiently close to the age of completed fertility, and birth rates after the age of 40 years are not significantly different between women with or without FGC (analysis not presented here). Any respondents with offspring whose date of death was flagged as unreliable were excluded. All individuals who met these criteria were included, giving 10,067 women aged 40-49 years who were from a major ethnic group and who had given their FGC status. The surviving offspring data was normally distributed, and assumptions justifying the use of linear regression were met.

We first analysed the relationship between FGC frequency and fitness in each country separately using aggregate data. We calculated the percentage difference in the average number of surviving offspring for women with and without FGC in each ethnic group, and performed Pearson's bivariate

correlation (two-tailed) to examine the association between this measure and ethnic FGC frequency. Ethnic groups with fewer than five individuals with or without FGC were omitted from the analysis as the variance of their means is excessive.

For the main analysis we performed a three level regression model (level 1: individual n10,067, level 2: ethnic group: n47, level 3: country n5) controlling for individual-level variables; mother's FGC status, education (no education/some education), religion (Muslim/non-Muslim), and wealth (quintiles). Ethnic FGC frequency was added as a level 2 contextual variable and we also included a cross-level interaction between FGC status and ethnic FGC frequency which allows for the effect of FGC status to vary depending on FGC prevalence in the ethnic group. Although no covariates in the model relate to country (level 3) it is retained in the model to allow for analysis of residual variance at this level. The model is expressed as;

$$y_{ijk} = \beta_0 + \beta'x_{ijk} + v_{0k} + u_{0jk} + e_{ijk} \quad (4)$$

where y_{ijk} is the response, β_0 is the intercept, $\beta'x_{ijk}$ are the predictor variables at all levels, v_{0k} is the random effect at country level, u_{0jk} is the random effect at the ethnic group level for ethnic group j in country k , and e_{ijk} is the random effect at the individual woman level.

MLwiN version 2.35 was used for multilevel modelling, and SPSS v23 was used in other analyses.

Data Availability

The datasets analysed during the current study are available by request from The Demographic and Health Surveys Program [<https://dhsprogram.com/>].

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Acknowledgements

We would like to thank Fiona Jordan, David Lawson and Alarna Samarasinghe for their helpful comments on previous drafts, and Richard Parker for MLwiN guidance.

Author contributions

JH and MG conceived and designed the study, JH performed data analysis, JH and MG wrote the paper.

FIGURES

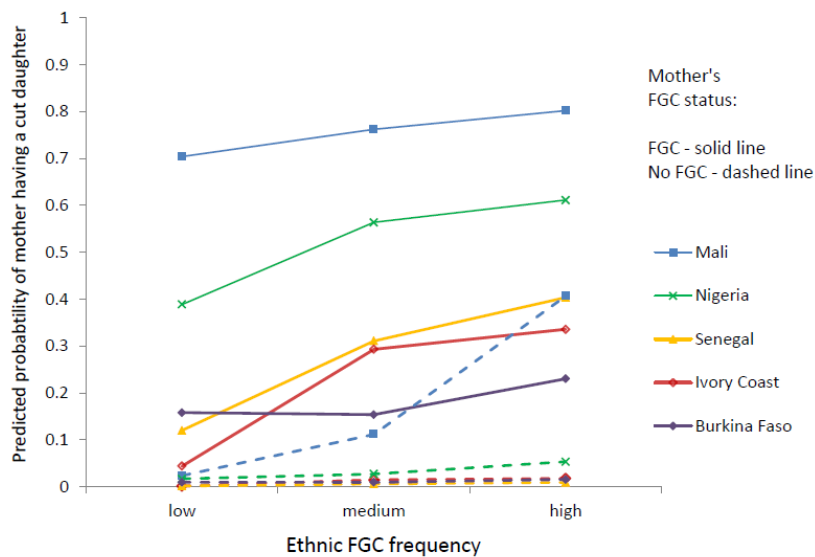


Figure 1: Predicted probabilities of having a cut daughter by mother's FGC status and country at different ethnic FGC frequencies. (Mali n7,634, Nigeria n7,916, Senegal n6,941, Ivory Coast n3,241, Burkina Faso n10,305). Predicted probabilities calculated from single-level logistic regression model controlling for mother's wealth, education, religion and age. In the model ethnic FGC frequency was a continuous variable, values are grouped into tertiles here for visual clarity.

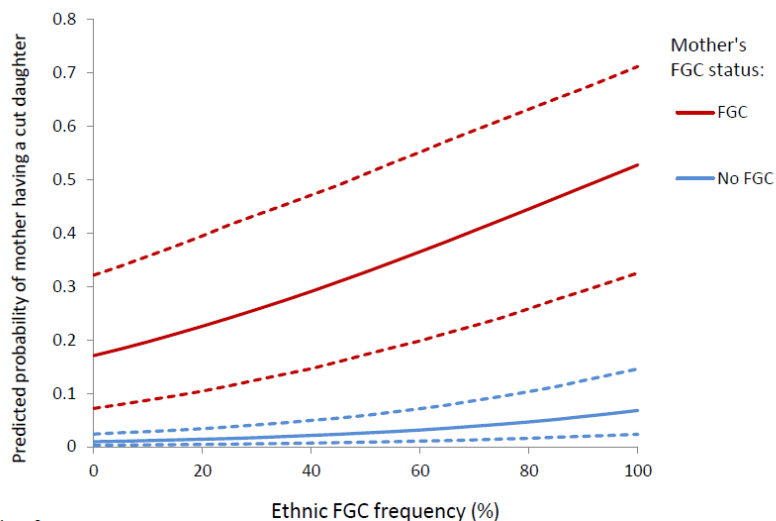


Figure 2: Predicted probabilities of having a cut daughter by mother's FGC status at different ethnic FGC frequencies. (level 1: individual n36,038, level 2: ethnic group n47, level 3: country n5). Predicted probabilities calculated from multilevel logistic regression model controlling for mother's wealth, education, religion and age. Dotted lines = 95% confidence intervals.

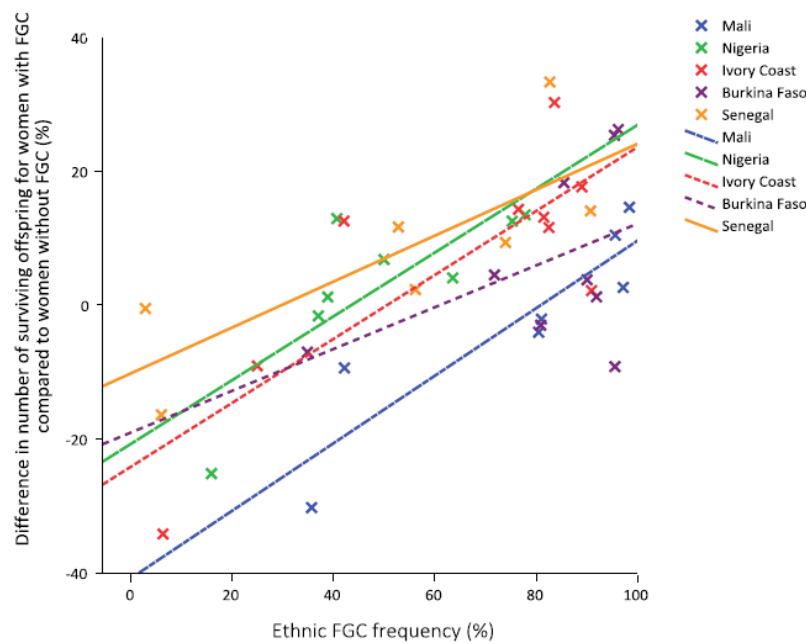


Figure 3: Correlation between ethnic FGC Frequency and the percentage difference in average number of surviving offspring for women aged 40-49 with FGC compared to women without FGC (Mali n1,650, Ivory Coast n847, Nigeria n2,274, Burkina Faso n 2,512, Senegal n1,866)

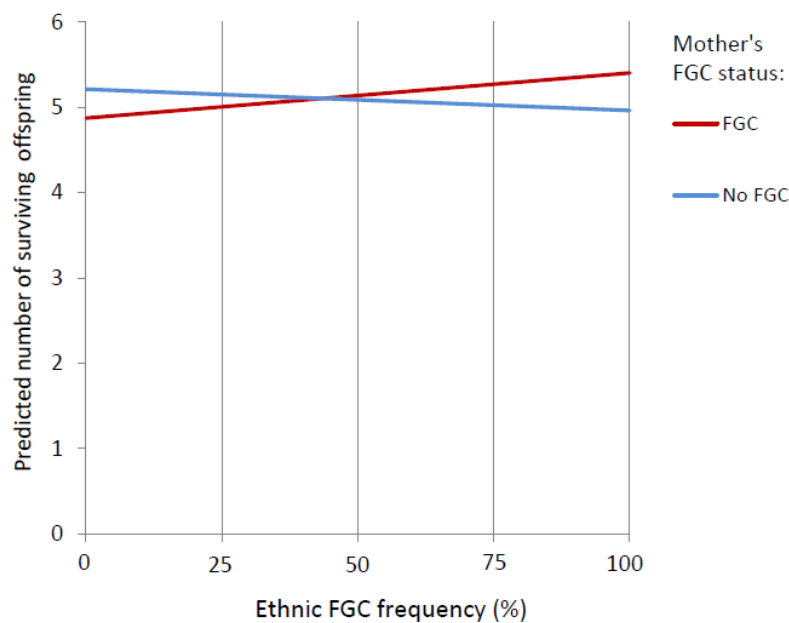


Figure 4: Predicted number of surviving offspring by mother's FGC status and ethnic FGC frequency (level 1: individual n10,067, level 2: ethnic group: n47, level 3: country n5). Predictions calculated from multilevel linear regression model controlling for mother's FGC status, religion, education and wealth.

TABLES

Country	Ethnic Groups n	Women n	Pearson's R	p value
Mali	7	1,650	0.899	0.006
Ivory Coast	9	847	0.804	0.009
Nigeria	8	2,274	0.793	0.016
Burkina Faso	9	2,512	0.445	0.279
Senegal	7	1,866	0.794	0.033

Table 1: Pearson's correlation between ethnic FGC Frequency (%) and the percentage difference in average number of surviving offspring for women aged 40-49 in each ethnic group with FGC compared to women without FGC.

Parameter	β	S.E.	p value
Fixed Effects			
Constant	5.125	0.145	0.000
Mother's FGC status (<u>No</u> /Yes)	-0.339	0.188	0.070
Mother's education (<u>None</u> /Some education)	-0.409	0.066	0.000
Mother's wealth (<u>lowest quintile</u>)			
Second	-0.091	0.069	0.191
Third	-0.189	0.070	0.007
Fourth	-0.265	0.075	0.007
Highest	-0.743	0.070	0.000
Mother's religion (<u>Christian or other</u> /Muslim)	0.110	0.069	0.108
Contextual Effects			
Ethnic FGC (%)	-0.003	0.002	0.302
Cross level Interaction			
Ethnic FGC% x Mother's FGC status	0.008	0.003	0.005
Random Part			
Variance level 3 (Country)	0.000	0.000	0.998
Variance level 2 (Ethnic group)	0.139	0.038	0.000
Variance level 1 (Individual)	5.522	0.138	0.000

For categorical variables, the reference category is underlined

Table 2 Multilevel linear regression model analysing number of surviving offspring born to women aged 40-49 (level 1: individual n10,067, level 2: ethnic group: n47, level 3: country n5)